EVOLUTIONARY EFFECT IN QUASARS AS A CONSEQUENCE OF GALAXY FORMATION PROCESS

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Many years ago M. Schmidt established the presence of a strong evolutionary effect in quasistellar objects (QSOs). Though this important problem is not yet fully resolved, there can be no doubt that in earlier epochs of the Universe evolution of the spatial density of QSOs (in the comoving coordinates) was much higher than it is now. Thus, for instance, the spatial density of the optically selected QSO is:

$$\rho = \rho_0 \, e^{10\tau}$$

according to Schmidt (1977). Here $\tau = z/(1+z)$, whence, for instance, if $z = 3$, $\rho \sim 1000\ \rho_0$, where ρ_0 is the local density.

On the other hand, the density of QSOs ceases to grow at a redshift somewhere between $3 < z < 4$. According to Osmer (1981), the spatial density of QSOs decreases considerably for $3.7 < z < 4.7$. The available, though unfortunately still insufficient, data make it possible to state that the spatial density of QSOs has its maximum near $z \sim 3$, and the "effective width" of their distribution is $|\Delta z| \sim 0.5$.

That there is an "epoch of quasar formation" at about $z \sim 3 \pm 0.5$ in the history of the Universe is the most natural conclusion from the above distribution. The interval

$$T = (1.3 \text{ to } 1.9) \cdot 10^9 \text{ years}$$

of the Universe age corresponds to that epoch. Here the age of the Universe (for the closed model) is given by:

$$T = T_0(1+z)^{-3/2}; \quad \Delta T = 3/2\ T_0(1+z)^{-5.2}\ \Delta z\ ,$$

where $T_0 = 2/3\ H$. For a Hubble constant of 50 km/s, $T_0 \doteq 13 \cdot 10^9$ years. Thus, the evolutionary effect in the case of QSOs is most naturally explained by the fact that the overwhelming majority of QSOs formed at a certain stage of the Universe's evolution, when it was about two billion ($2 \cdot 10^9$) years old. What stage is that?

With a good degree of certainty we may now state that QSOs are galactic nuclei with an extremely high level of activity. Therefore,

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the epoch of QSO formation is the epoch when galactic nuclei were forming. The almost-normal (that is, solar-like) chemical composition of the plasma-radiating QSO emission lines is a convincing argument in favor of the concept that QSOs are closely associated with the nuclei of galaxies. As far back as 1964, we emphasized that the phenomenon was not trivial (Shklovsky 1964).

It is most evident that a protogalaxy forming from diffuse matter needs time -- and a long time, indeed -- to develop a nucleus (and a disk, too) with the "normal" chemical composition. The suggested interpretation of the evolutionary effect implies that it should be $T_1 \sim (1.6 \pm 0.5) \cdot 10^9$ years. Therefore, we may estimate the epoch when protogalaxies started forming from the initial inhomogeneity of the matter in the Universe. The beginning of contraction of such inhomogeneities under the effect of gravitational instability is at

$$T_2 = T_1/2 ;$$

whence: $z_2 \sim 5$.

The estimates of T_1, T_2 and z_1 derived above are obviously most tentative. We have used simplified cosmological relationships, valid for the case $\rho = \rho_\alpha = 3H^2/8\pi G$. Since at present it is not yet clear which model, open or closed, is valid for the Universe, the above estimates may differ much from the real values. Our aim is to emphasize the explicit connection between the evolution of the Universe and the statistics of observational data for QSOs.

In the framework of the interpretation suggested here for the QSO evolutionary effect, a specific problem of comparatively near ("local") objects arises. The point is that the QSO phenomenon should be fairly short-lived. Hence, it is wrong to assume that local QSOs have been emitting over cosmological periods of time. There are two possibilities to explain the phenomenon of local QSOs:

a) Local QSOs are associated with quite recently formed nuclei of galaxies. It implies an assumption of a continuing formation of galaxies from the intergalactic gas in the expanding Universe;

b) Local QSOs are associated with the "rejuvenation" (activation) of the nuclei formed long ago. "Cannibalism" processes in the world of galaxies, gaining enhanced attention in recent years, may be mentioned as a cause of such "rejuvenation." Not abandoning, in principle, "cannibalism" as a possible reason for a temporary increase in the activity of galactic nuclei, we believe the phenomenon of local QSOs should be explained by a continuing process of the formation of the galactic nuclei in the Universe. The process should be regarded as slowing down, for at $z = 2$ to 3, its rate was hundreds of times higher than in our epoch.

It might be argued that the "cannibalism" hypothesis is supported by the recent discovery of three companions near QSOs (Stockton 1980). In our view, however, this is but another fact favoring the concept of QSO localization in poor clusters. As is known, similar companions are observed at about the same distance in the vicinity of M31 and other near galaxies, M87 among them. The fact of galaxy interaction alone does not imply a likelihood of their "rejuvenation."

On the contrary, new supporting arguments have recently been offered in favor of the hypothesis of a continuing process of galactic nuclei formation. The galaxy NGC 5128 has been considered by many authors to be a classical example of "cannibalism." However, recent thorough studies of NGC 5128 have shown no traces of a collision of two galaxies there. Everything indicates that a newly (about 10^9 years ago) formed disk -- and therefore a nucleus -- is observed in this galaxy. Note that Cygnus A and some other objects belong to the same class of galaxies. Another argument is provided by recent studies of the age of the disk and nucleus populations in our Galaxy; the age of the oldest stars in the disk appears to be at most $\sim 7 \cdot 10^9$ years (O'Connel 1980). Apparently, the nucleus of our stellar system formed only when the age of the Universe was already about ten billion $(10 \cdot 10^9)$ years, that is, $z \sim 0.5$, whereas the overwhelming majority of nuclei of other galaxies in the Universe formed at $z \sim 2$ to 3.

Observations of recent years lead us to the idea that even within one cluster the time required for nuclei of constituent galaxies to form may vary over a large scale. A natural assumption is that galactic nuclei form more rapidly in the clusters with a higher initial density, since they have a shorter free-fall phase of gravitational contraction. The conditions for the condensation of more rarefied clouds might possibly be more favorable at cluster peripheries.

Attention should be drawn to the fact that the gas of which our protogalaxy formed was not yet enriched by heavy elements -- in particular, iron. It may mean that the condensation started prior to the formation of an intergalactic hot plasma in the cluster, the plasma being rich in heavy elements. We may also imagine the formation of protoclusters of galaxies at $z < z_1$, which, having a comparatively low mean density, should evolve much slower. It may explain the observed situation whereby local QSOs mainly occur in poor clusters with lower densities.

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